

IMT-2000 SATELLITE STANDARDS WITH APPLICATIONS TO MOBILE AIR TRAFFIC COMMUNICATIONS NETWORKS

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Abstract

The International Mobile Telecommunications – 2000 (IMT-2000) standards and more specifically the Satellite component of it, is investigated as a potential alternative for communications to aircraft mobile users en-route and in terminal area. Its application to Air Traffic Management (ATM) communication needs is considered. A summary of the specifications of IMT-2000 satellite standards are outlined. It is shown via a system research analyses that it is possible to support most air traffic communication needs via an IMT-2000 infrastructure. This technology can compliment existing, or future digital aeronautical communications technologies such as VDL2, VDL3, Mode S, and UAT.

Introduction

Over the next 20 years, it is expected that the demand for air travel will double. This will in turn cause increased delays and capacity bottlenecks unless new measures are taken.

Several research and Industry organizations are actively involved in modernizing the air space to alleviate those future problems such as the Advanced Air Transportation Technologies (AATT) Project. AATTs objective is to improve the overall performance of the National Airspace System (NAS) as a whole [1].

A critical element of the modernization effort revolves around the communication technologies. Digital links are being developed to replace existing analogue voice systems for communications, as well as for surveillance (examples of links: VHF Digital Links VDL2, VDL3, and examples of applications: Automatic Dependent Surveillance Broadcast ADS-B, Controller Pilot Data Link Communications CPDLC, Traffic

Information Services TIS, and Flight Information Services FIS).

This system level paper addresses the possible application of the Satellite IMT-2000 technologies within ATM communications. The benefits of the technologies are highlighted along with their disadvantages. The next four sections will cover in order; an overview of the Satellite IMT-2000 technology, an overview of the ATM applications and communication links technology relevant to this paper topic, followed by the application of IMT-2000 to the ATM, and ending with the Conclusions section.

International Mobile Telecommunications (IMT-2000) Satellite Component Standards

3G Systems are expected to provide universal mobility with a range of services including paging, messaging, telephony, and Internet and broadband data. The International Telecommunication Union (ITU) has been involved in defining the standards for third generation systems, referred to as International Mobile Telecommunications 2000 (IMT-2000).

Initial work on standardization had started by the middle of the 1980s although practical work did not start until the 1990s with the allocation of 230 MHz bandwidth for IMT-2000 between 1885 and 2025 MHz, and between 2110 and 2200 MHz. Within those two bands satellite communications occupies a portion from 1980 to 2010 and also from 2170 to 2200 which totals to 60 MHz. Several dedicated committees were organized that influenced the satellite components of the IMT-2000 standards development including the European Space Agency (ESA), telecommunications standardization body in Ko-

rea, INX Iridium Operating LLC, ICO Global communications, and Inmarsat. In addition to those bodies which influenced the satellite component of the IMT-2000 standard, there are also several bodies that created the terrestrial standards. Those organizations included the European Telecommunications Standards Institute (ETSI), Association of Radio Industries and Businesses (ARIB), Telecommunications Technology Association and Committee (TTA and TTC), China Wireless Telecommunications Standard Group (CWTS). In addition to the standardization organizations there were several Market Representative Partners that included IPv6 Forum, and CDMA Development Group (CDG), GSM association, among others.

The satellite and terrestrial IMT-2000 elements are to be complimentary with each other with satellite coverage being Global and covering areas where the terrestrial components are not available. While the specifications for terrestrial standard come from five standards (out of 10 original proposals), the specifications for the satellite component come from six different standards which will be summarized in this section [2-3].

For completeness, we first list the terrestrial IMT-2000. Those standards are as follows:

- CDMA Direct Spread (also called Universal Terrestrial Radio Access (UTRA) FDD or wideband CDMA (WCDMA).
- The CDMA Multi-Carrier also called CDMA2000 which consists of the 1X and 3X components.
- CDMA Time Division Duplex TDD, also called UTRA TDD with a 1.28 Mcps TDD (TD-SCDMA) option, and a 3.84 Mcps TDD.
- TDMA single carrier, also called Universal Wireless Communications-136, specified by the American National Standards TIA/EIA-136 and designed to maximize compatibility with the GSM general Packet Radio Service (GPRS).
- FDMA/TDMA standard, which is also called Digital Enhanced Cordless Telecommunications (DECT).

The satellite standards which are a part of the IMT-2000 deal mainly with the service link, which is the link between the satellite and the Mobile Earth Station (or User Terminal UE). The other links which include the two way Feeder link between the satellite and the ground stations, and the inter-satellite link between multiple satellites if more than one satellite is used, are not governed by IMT-2000 standards. The feeder and inter-satellite links specifications are governed and specified by the satellite system designer standards. Additionally, the requirements from the satellite link to terrestrial link and vice versa are not part of the IMT-2000 standard. On the other hand, the interface from the satellite system (satellites and earth stations) to the Core Network will follow standards that are very similar to the terrestrial interface to the Core Network. Those requirements affect call routing, billing, roaming mechanism, and other functions.

The six satellite system standards comprising the satellite specifications of the IMT-2000 are discussed next. Due to large amount of details only a portion of the full set of specifications is shown for each standard. Those six standards come from various standards bodies with the common purpose of providing satellite services to complement the terrestrial network.

The first Service Link Specification for the satellite radio interface is termed the "A Specification" and is developed by the European Space Agency ESA. That system is also called the SW-CDMA standard. It is based largely on the CDMA Direct Spread terrestrial radio Interface (UTRA FDD).

The interfaces from the core network to the Satellite system (satellite, earth stations) will follow the same standard as the IU interface in the terrestrial network, which is the interface between the Core Network and the Radio Network Controller (RNC). Also the core network architecture will be same as that for the terrestrial counterpart. The main features as well as the differences from the UTRA FDD terrestrial standard include:

- Maximum rate of 144 Kbit/s and the minimum 1.2 Kbit/s.

- BER from 1×10^{-3} to 1×10^{-6}
- Satellite diversity in reverse link when more than one satellite is used.
- Supported by Bent pipe constellation LEO, MEO, GEO, or HEO is possible.
- Maximum tolerated delay of 400 ms.
- Doppler precompensation for service and feeder links.
- 2 vs. 3 forward link acquisition.
- Half frequency chip rate for improved granularity.
- High powered paging channel for indoor operation (not applicable for aircraft with external antennas but may prove useful in other settings)
- Reduce power control rate with closed loop control for forward and return links, in addition to outer loop control based on FER. Power control range is 20 db, power control step is 0.2-1.0 db, and power control rate is 50 to 100 Hz.
- Longer preamble sequence for random access.
- Two chipping rates 1.92 and 3.84 Mc/s that occupy 2.35 and 4.7 MHz of bandwidth in each direction.
- Frame period of 10 ms and 20 ms for the long and short chip rates. Multi Frame of 8 frames (4 frames for half rate), and a super frame of 9 Multi Frames for the full rate option. 15 time slots per frame exist.
- Three classes of services are supported with: standard service (uses 1/3 or 1/2 convolutional constrained length $k=9$, polynomials 557, 663, 711) and interleaving with BER of 1×10^{-3} . High quality with inner 1/2 or 1/3 convolutional coding and interleaving and outer RS coding with Turbo Coding optional, and BER of 1×10^{-6} . Services that have specific coding needs where higher layers will manage the coding scheme.
- Modulation is done with QPSK for the Full rate and BPSK for the half rate in the downlink, and Dual Code BPSK for the uplink.

- Spreading is done with Complex quaternary sequence of length 2560 chips. Same code can be used in different satellite spot beams. Channel codes are orthogonal variable spreading factor (OVSF) codes that assures orthogonality of forward channels.
- Handoff could be beam, intersatellite, inter earth station, and inter frequency using C/(N+I) with User or Earth station making the final decision. Soft hand off is also supported.
- Maximum EIRP for UT that is of the Vehicular type is 16 dBW, with G/T of -23.5 dB/K for a LEO constellation and -20.0 dB/K for a GEO.
- There is a 500 Km/h for ground vehicular mobility restriction specified, although modification with upgraded equipage may resolve that limit for En-route air traffic.

The B Satellite Radio interface is the SW-C/TDMA also by ESA. Some of the features of this system include:

- Based on a hybrid code and time division multiple access
- Channel bandwidths of 2.35 or 4.7 MHz in each direction of transmission for 1.920 Mc/s half rate, or 3.840 Mc/s full rate.
- Bearer services range from 1.2 to 144 Kbits/s with BER supported from 1×10^{-3} to 1×10^{-6} .
- Can be used with a bent pipe or regenerative LEO, MEO, GEO, or HEO constellation.
- Maximum delay tolerated of 400 ms.
- Satellite diversity in multiple satellite scenario is supported
- Frames are 20 ms in period divided to 8 slots with Multi Frame comprising 8 ordinary frames with one additional frame.
- Closed loop power control for forward and return links, with slower outer control loop based on FER measurement to set the target power value. Also open loop control for packet transmission and for initial setting of power is provided. Power control specifica-

tions (range, control step, rate) are similar to the A standard.

- Modulation is QPSK or dual code BPSK in the uplink and QPSK or BPSK for low data rate in the downlink.
- Coding is done with convolutional 1/3 or 1/2 constrained length 9, with RS over GF(28) concatenated with the inner convolutional code with Turbo coding optional. Depending on the service class codes with or without RS are used with different levels of BER.

The C Satellite radio interface standard is the SAT-CDMA by the technical assembly of TTA of South Korea. This system is different than the previous ones in that it specifies the satellite constellation to be used. Some of the main features of this standard include:

- Use of a LEO satellite constellation using 48 satellites in 8 orbital planes with 54 degrees inclination with a 7.5 degrees of phase offset between orbit planes.
- Each satellite will have 37 spot beams each having a diameter of approximately 519 km.
- Packet data services will range from 2.4 to 144 Kbits/s.
- The feeder links are at 4/6 GHz while the inter satellite links at 60 GHz. (although this was not a part of the standard as previously explained)
- Various types of satellite handoffs are possible.
- Closed loop power control supported.
- The channel bandwidth is 5 MHz.
- Convolutional coding and Turbo coding is used in SAT-CDMA with constraint length 9 and coding rates 1/3 and 1/2.
- Orthogonal complex QPSK modulation is used for uplink with long code direct sequence spreading, and QPSK is used for the downlink with short code spreading for channelization and long code spreading for scrambling.

The D Satellite radio interface is SRI-D by ICO Global Communications is again specific to a constellation and is basically comprised of:

- 12 MEO satellites in 2 orbits inclined at 45 degrees, with 12 Earth stations.
- Each satellite will have 163 spot beams.
- Modulation is done with QPSK on downlink and GMSK on uplink, as well as BPSK depending on channel type.
- Convolutional coding with rate 1/6 up to 1/2 is used again depending on carrier type. Data rates range from 2.4 Kbits/s up to 38.4 Kbits/s depending on Terminal type with BER at 10⁻⁵.
- RHCP polarization is employed in the uplink and downlink.
- Frequency reuse of 4 is used.
- Satellite EIRP ranges from 58.2 up to 56.1 dbw with worst case G/T of 1.5 dB(K-1).
- A combination of FDMA and TDMA in each 25 kHz RF carrier is used.
- 40 ms frames supporting 6 TDMA time slots are specified.

The E Satellite radio interface (SRI-E) by Inmarsat (Horizons) is a standard that have been optimized for a geostationary satellite configuration with worldwide coverage and multimedia services. Some of the main features of this system include:

- Geostationary satellite configuration
- Forward link can deliver between 21.6 kbit/s to 512 kbit/s. Return link able to support 19.2 kbit/s up to 512 kbit/s.
- Up to 300 spot beams per satellite, with 1 degree beam widths (800 Km diameter)
- Frequency reuse of 7 beam cluster.
- Average G/T of satellite beam of 10 dB/K with saturation EIRP of maximum 53 dBW (minimum 38 dBW) and a satellite total of 67 dBW. Satellite EIRP per RF carrier of 43 dBW.

- Power control with step size of 0.5 dB, and a dynamic range of 8 dB, with 1 cycle per second rate.
- It makes no assumptions on the protocols used in the upper OSI layer allowing any type of traffic that can fit within the bandwidth.
- Location management service with the use of GPS.
- Dynamic channel allocation where frequencies are assigned to spot beams based on traffic load.
- TDM/TDMA/FDMA multiple access
- To support a wide range of antenna specifications and EIRP levels, a range of bearer services are used with different modulation schemes. 16-QAM and 4-ary modulation is used in the return link. 16-QAM and QPSK is used for the forward link.
- Variable coding (puncturing of turbo codes in a pre-defined manner) is used to maximize efficiency and bit rates possible to achieve for each terminal.
- Frame/burst durations of 80 ms in forward direction and between 5 and 20 ms in return direction.

The Satellite radio interface F specification by Iridium is called Satcom2000. It promotes the use of smart antennas, hybrid multiple access schemes, on-board processing and switching, with other advanced technologies, to optimize spectral, spatial and power resources. Some of the features of this system include:

- Consists of 96 LEO satellites in 8 near polar orbits, 12 satellites per orbit in addition to the spares. Satellite coverage is over the entire earth.
- 228 spot beams per satellite (can be adjusted to improve performance)
- 15 degrees minimum user elevation.
- Inter satellite links, with onboard processing, with dynamic beam traffic distribution.

- Uses both FDMA/TDMA and FDMA/CDMA access technologies on every satellite in order to support diverse communication needs.
- Supports bandwidth on demand, bit rate on demand, asynchronous data, and asymmetric data.
- Minimum satellite channelization of 27.17 kHz in TDMA, and 1.25 MHz in CDMA.
- QPSK modulation with TDMA, and 16-QAM/QPSK for CDMA.
- FEC for TDMA is 2/3 convolutional, and for CDMA 1/2 convolutional in down link, and 1/3 in uplink. In addition outer RS will be used, as well as ARQ for non-real time services.
- Data link using multiple channels can be used to provide up to 144 kbits/s.
- Supports up to 500km/h for hand held and 5000 km/h for aero.
- It will operate a service link at the 2 GHz band. Separate bands will be allocated for the CDMA and TDMA components. FDD used for transmit and receive in CDMA mode with 63 dB isolation in between.
- Power control rate for CDMA is maximized at 50 Hz. Power step of 0.5 dB in CDMA and 2 dB in TDMA with power control range of 25 dB.
- Maximum satellite EIRP of 29.6 dBW, maximum satellite G/T of 0.1 dB/K.
- Frequency stability of 0.375 ppm uplink, 1.5 ppm downlink.
- Doppler compensation.
- Fade margins of 45 dB for messaging and 15 to 25 dB for voice.
- Frame length of 40 ms, with 4 time slots in each.

Having covered all six standards in a summarized format, it is worth noting that there were many other specifications that interested readers have to obtain from various standards and documents that could not all be mentioned here.

The next section will next introduce the ATM communications system, and the satellite sub-component standards currently accepted by the Federal Aviation Administration and the RTCA committees, which will then lead the way to a study of the possible application of the IMT-2000 standards to the ATM applications.

ATM Communications System and the Satellite subsystem specifications

The air traffic management modernization effort has resulted in advancements in the communication technologies and their applications. Table 1 from [4] below summarizes those applications. With the exception of the passenger service (APEX), all other services are key elements of the ATM communications infrastructure. Some of those services can be localized to regional areas while others are broadcasted over wider areas such as the entire CONUS. For example CPDLC communication is well suited for local region while TIS and FIS can be broadcast over the entire CONUS giving pilots and crew situational awareness and additional ability to plan ahead. All services currently have their designated links although studies have shown that some of those links could reach a capacity limit requiring additional alternative links. Table 2, also from [4] shows the capacity provided by various communication links currently proposed for ATM. The satellite portions shown in the Table are not currently employed or specified and hence a system based on the IMT2000 standard can serve as a bench mark for experimental testing initially and full implementation at a later stage utilizing the capabilities and advantages of having a global standard and possibly much more affordable equipment.

Table 3 [4] shows estimated data rates for the applications in Table 2, by year 2015. Those data rates correspond to three domains defined over 10 minutes for the airport and terminal, and 50 minutes for the en route. The loads shown hence corresponded to (based on work in reference [4]) 192, 137, and 500 aircraft for the air-

port, terminal, and en route domains respectively. Hence if we are interested in obtaining traffic per aircraft, we may simply divide the numbers shown in the table by the number of aircraft just stated. This is useful if we want to vary the traffic load based on larger geographic areas, or if we simply want to look at traffic loads of various number of aircraft in general.

Application	Definition
Flight Information Services (FIS)	Aircraft continually receive Flight Information to enable common situational awareness
Traffic Information Services (TIS)	Aircraft continually receive Traffic Information to enable common situational awareness
Controller - Pilot Communication (CPC)	Controller - Pilot voice communication
Controller-Pilot Data Link Communications (CPDLC)	Controller - Pilot messaging supports efficient Clearances, Flight Plan Modifications, and Advisories (including Hazardous Weather Alerts)
Decision Support System Data Link (DSSDL)	Aircraft exchange performance / preference data with ATC to optimize decision support
Automated Dependent Surveillance-Broadcast (ADS-B)	Aircraft continuously broadcast data on their position and intent to enable optimum maneuvering
Airline Operational Control Data Link (AOCDL)	Pilot - AOC messaging supports efficient air carrier/air transport operations and maintenance
Automated Meteorological Transmission (AUTOMET)	Aircraft report airborne weather data to improve weather nowcasting/forecasting
Aeronautical Passenger Services (APAXS)	Commercial service providers supply in-flight television, radio, telephone, entertainment, and internet service

Table 1. ATM Communication System Applications [4]

Data Link	Single Channel Data Rate	Capacity for Aeronautical Communications	Channels Available to Aircraft	# Aircraft Sharing Channel (Expected Maximum)	Comments
	kbps	Channels	Channels	Aircraft	
HFDL	1.8	2	1	50	Intended for Oceanic
ACARS	2.4	10	1	25	ACARS should be in decline as users transition to VDL Mode 2
VDL Mode 2	31.5	4+	1	150	System can expand indefinitely as user demand grows
VDL Mode 3	31.5*	~300	1 CPDLC 3 or 4 Voice	60	Assumes NEXCOM will deploy to all phases of flight
VDL Mode 4	19.2	1-2	1	500	Intended for surveillance
VDL - B	31.5*	2	1	Broadcast	Intended for FIS
Mode-S	1000**	1	1	500	Intended for surveillance
UAT	1000	1	1	500	Intended for surveillance/FIS
SATCOM	-	-	-	-	Assumes satellites past service life
Future SAT-COM	384	15	1	~200	Planned future satellite
Future Ka Satellite	2,000	~50	~50	~200	Estimated capability - assumes capacity split for satellite beams
Fourth Generation Satellite	>100,000	>100	>100	Unknown	Based on frequency license filings

* Channel Split between voice and data

** Limited to a secondary, non-interference basis with surveillance and has capacity of 300 bps per aircraft in track per sensor

Table 2. Aeronautical Communication Links Capacities [4]

Data Message Traffic for All Classes of Aircraft (K-bits per second)						
2015	Airport Uplink	Airport Downlink	Terminal Uplink	Terminal Downlink	En Route Uplink	En Route Downlink
FIS	0.2	0.0	0.9	0.0	6.9	0.0
TIS	23.7	0.0	7.0	0.0	20.5	0.0
CPDLC	3.4	2.9	1.3	0.9	1.1	1.3
DSSDL	0.2	0.3	0.1	0.2	0.1	0.1
AOC	0.4	8.4	0.6	8.5	0.2	3.5
ADS Reporting	0.0	16.1	0.0	3.3	0.0	1.5
AUTOMET	0.0	0.0	0.0	4.4	0.0	6.2
APAXS	0.0	0.0	0.0	0.0	131.7	115.5

Table 3. Estimated Peak Communication Loads for 2015 [4]

The satellite standards currently accepted and circulated by the RTCA committee, ICAO, and the FAA have developed independently of the IMT-2000 standards and no direct or indirect relationship exist between the two. None the less there were several common to both standards

contributors such as Inmarsat, Iridium, ICO, among others. It is the purpose of this paper to show any possible application or commonalities that could be exploited for the benefit of making the technology destined to the passengers of the aircraft (users of the future IMT-2000 service),

also be utilized by the cockpit crew and possibly reducing costs. The aeronautical services satellite standards originally were embodied by the Annex 10, International standards and recommendations practices for Aeronautical Telecommunications by ICAO [5] and RTCA [6]. Those standards were largely based on the Inmarsat GEO satellite maritime legacy services. In order to keep up with modern technologies, a second set of standards was being developed with the help of the RTCA committee, and with the intention of including it into the Annex 10 ICAO standards [7]. Those second set of standards [7-9], did not rely on the legacy Inmarsat service and opened the door for various possibilities so that newer satellite systems can be accommodated that are not necessarily using GEO constellations, or any of the other specifications of the Inmarsat legacy service. Table 4 lists a brief summary of some of those second set of specifications.

It can be concluded from those standards and the standards for the IMT-2000 discussed in the previous section that several advantages as well as disadvantages exists. For example, the advantages of the IMT-2000 would include:

- Meets most of the data, and voice requirements and recommendations of the aeronautical satellite services of Table 4 with margin (example transfer delays, call origination).
- Constellations open to various architectures in both standards (GEO, LEO, MEO)
- Coverage is world wide for both systems
- IMT-2000 equipage in the future may prove to be cost effective due to the global usage of the systems and the large number of users. Therefore cockpit equipage may require general enhancements only. In particular, it is most likely that any IMT-2000 service in the future will target airline passenger in flight, hence requiring aircraft equipage as well, such a passenger service can make the cockpit service less costly to implement.

Performance parameter	Specification
Coverage	World wide service.
Mean transfer delays of packet data	23-28 seconds
95 th percentile transfer delay of packet data	25-30 s to aircraft 40-60 s from aircraft
Priority for data services	Priority for safety communications (3 levels). Preemption over non-safety services if necessary
Integrity of packet data	1×10^{-6} for a block of 128 octets
Connection establishment delay	Maximum 50 seconds 95 th percentile for connection oriented protocol
Constellation	GEO, LEO, or MEO
Frequency	1554-1555 MHz space-to-earth, 1646.5-1656.5 MHz in earth-to-space. Also 1610-1626.5 MHz is used.
Acquisition of signal and tracking speed	Can acquire and track aircraft up to 1500 km/h speeds (800 knots) with 2800 km/h (1500 knots) recommended
Interference	Each aircraft shall not cause more than -115 dBW/MHz in average spectral density in AMSS band (measured over 20 ms period) when operating in max power
Susceptibility	Can operate in an environment of up to 25% change in receiver temperature
Voice call blockage	No more than 0.01
Security	Protection against denial of service, degraded performance, reduction of system capacity
Voice service interface	Should conform to recognized international telephony standards when interfacing with external telephony networks
Transfer delay on connected channel for speech	.485 second maximum from time speech exists Aircraft to time enter Ground station and vice versa.
Recommend maximum aircraft attitudes while meeting performance	+20/-5 degrees in pitch, +/-25 degrees in roll

Table 4. RTCA/ICAO Mobile Satellite Services for Next Generation [7-9]

- IMT-2000 will have several more features than the aeronautical service and high enough data rates to open the door to future applications not listed in previous section. This is evident from the application data rates of Table 3, and the 144 Kb/s available capability.
- Previous analytical studies [10] have shown that it is sufficient to have a 1 Kb/s source data rate to send CPDL-C, ADS, TIS, and FIS information in the return link and accommodating projected traffic demands in year 2020 (up to 9000 aircraft in flight projected). IMT-2000 satellite standards provide considerable margin for the data capability in the return links as shown in previous sections. For the forward link, on the other hand, analyses done in [10] concluded the need for a 10 MHz band to transmit TIS, FIS, and CPDLC information about all the CONUS. That requirement was mainly governed by the large amount of TIS information to be sent for all aircraft of the CONUS. Since IMT-2000 will have a 2 way communication capability, such a requirement will not be necessary if a system is set up such that aircraft users can request regional TIS information based on flight planning needs.
- Multicasting, paging, are additional features in IMT-2000 standards that can prove to be useful in air traffic management.
- Currently several systems such as the Iridium, AirCell, as well as Inmarsat, offer or have been tested to offer aeronautical services. Example is work in Alaska on Capstone project [11]. Since the contributing partners to these current technologies are also partners in the future IMT-2000 satellite services, it is very likely that such new systems will try to tailor to the aeronautical market as well even though it is a narrow one.
- The foreseeable integration of Terrestrial and Satellite IMT-2000 services will prove to be very advantages for terminal area as well as en route over land. Note that the terrestrial services will be capable of providing data rates that are considerably higher than

the 144 Kb/s provided by the satellite component, with up to 2 Mb/s in micro-cell environment which can be very useful in terminal areas. Example of current systems using both satellite and ground services is the AirCell/Iridium service [12] which is based on 1 G technology and still capable of offering voice, low data (up to 9.6 Kb/s), and weather PDA display services.

- The RTCA/ICAO specifications for NGSS do not specify RF and base band technologies (example CDMA, or TDMA, modulation, coding, etc.). Therefore the researched links of the IMT-2000 technology are beneficial for any future system implementation.

Some of the disadvantages that can be foreseen if such a system is to be utilized:

- The frequency bands for the service links while both are within the L band (and lower S band), they are not the same. The AMSS band is protected for only aeronautical services and is a current requirement for new NGSS system proposals. The problem then lies in how to accommodate the IMT-2000 technology to an AMSS service. Hence the objective should be to utilize the technology and not simply the service. The other unlikely possibility is to have protected band within the current Satellite IMT-2000 bands for aeronautical services.
- AMSS and NGSS standards specify 3 classes of priority to be accommodated within any new system. IMT-2000 standards do have priority and class quality of service that can be exploited but require more research.
- IMT-2000 satellite standards are geared to vehicular users on ground and hence a maximum of 500 km/h is mentioned for a few of the interfaces. That limit was originally envisioned for users traveling in fast trains. Several of the interfaces do specify capability for aircraft, while others do not specify it and hence would require further research to investigate. It is likely that external mounting of antennas on aircraft will make the quality of service at high aircraft speeds compatible with the stated vehicular

standards but other alteration may also be needed depending on the interface chosen.

- TCP/IP is the accepted protocol to go on top of IMT-2000 physical interfaces. Although a few interfaces explicitly did specify the capability to be used along with any other data protocols, the rest did not specify that leaving the door for possible complications especially if the ATN protocol is the chosen one for aeronautical networks requiring more research.
- Lower data rate than the future but not yet realized satellite systems in Table 2.

Recommendations for Future Work

Given that an IMT2000 standard and service would prove to be a useful alternative with the terrestrial and/or satellite components, then further research can always pave the way for more findings. For example, employing a simulation using one or two of the interfaces outlined here with the aeronautical applications outlined can prove useful. Analytical results into the aeronautical environment can always prove to be useful as most current research covered ground users and not aeronautical users. Economics of the system, equipment, and market analyses can give a good indication on advantages or disadvantages of promoting such technologies. Finally, it is recommended that the most common terrestrial interface be taken into account when choosing the satellite portion. For example, currently (and this may change in the future) the UTRA (or UMTS with FDD) is the most widely accepted terrestrial standard. As such the SW-CDMA interface (direct spreading CDMA Satellite Interface or more commonly called S-UMTS with FDD) should be promoted to provide commonality with the terrestrial system and make use of the extensive research studies done globally on the Integration of the satellite and terrestrial elements of UMTS and S-UMTS [13-14]. In summary, this paper highlighted the benefits, and disadvantage of utilizing future 3G technologies and specifically the satellite component of it, for air traffic communications. Although there are many limitations, the advantages should not be discounted, and the possibly

of using the technology as an alternative or backup to any future aeronautical communications infrastructure should be exploited.

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